Earth & Environmental Sciences Division

News, Views & EEScience

Disclaimer: this monthly update is intended for internal distribution within the Earth and Environmental Sciences Division at Los Alamos National Laboratory and must not be distributed outside of LANL.

Safety

A Message from Jeff

Jeff Hansen, Division ES&H Officer, 667-5043, jchansen@lanl.gov

Chemical Inventory

If you have purchased chemicals for your work or the work of others here at the Laboratory there is a requirement that ANNUALLY the material is to be inventoried and its status must be updated on the LANL OII CHEM system (http://www.cm.lanl.gov/ex3/). The time frame is by December 31 of each year. Note that the 2002 deadline was extended to June 30, 2003, to accommodate the new tracking system). As of 6/16/2003, EES Division was only 81 percent complete. The goal is 95 percent or better by 6/31/03. If you need assistance in this endeavor, please contact Bill Hargraves at 7-7807 or
Jonathan Tapia at 7-9242. Listings were sent to each group office approximately six weeks ago describing who and what material needed to be updated.

Hazard Control Plans

All of the division's work must be authorized in some form by a hazard control plan. A line manager, referencing the specific hazard control plan, must authorize all personnel who are doing work for the division. If you are doing work and you are not sure if you have a hazard control plan, stop what you are doing and see your supervisor immediately. This applies to students, staff, and contractors.

Security

An Ear on the LIR from Tony

Tony Montoya, Acting Division Security Officer (DSO), 7-8065, antonio@lanl.gov

Peer-to-Peer Activity

Please be aware that due to significant security concerns, the Laboratory now has a policy that explicitly prohibits peer-to-peer (P2P) activity on the yellow network. Some popular examples of applications that utilize P2P networks are Kazaa, Limewire, and BitTorrent, to name a few. These applications are generally used for sharing files (particularly music) across the network.

Welcome Students!

Alexis Lavine, EES Student Liaison
7-3605, alavine@lanl.gov

We have an exceptional and diverse group of students this summer in EES Division. There are a variety of resources for both mentors and students to help ensure that the students have a positive educational and career development experience. Student internships at Los Alamos provide the student a unique experience, with opportunities to become familiar with the wide range of research being done here and opportunities to easily interact with a number of scientists. Mentors, please encourage your students to take advantage of the numerous seminars and activities. Please also provide career and academic guidance to your students. There have already been many student activities both within the Division and Lab-wide to help the students become familiar with EES, the Laboratory, and northern New Mexico. The EES Student and Mentor Orien-

tation and the Student Tour of EES were both very successful. We have recently developed an E-mail list for mentors in EES division and Alexis Lavine, the division Student Liaison, is keeping mentors and students informed of resources and activities through e-mail. Please inform Alexis if you are a mentor or a student and are not on one of these lists. Please check the Los Alamos Student Association Calendar of Events and the EES Student Calendar regularly for upcoming events.

Below are **web resources** for mentors and students:

EES **Student and Mentor Guidelines**: http://ees5db.lanl.gov/studhandbook/guidelines.html

EES Student Handbook: http://ees-www.lanl.gov/studhandbook/default.htm

EES Student Calendar: http://ees5db.lanl.gov/studhandbook/events.html

LANL Mentor Page: http://int.lanl.gov/education/mentors/index.shtml

LANL Student Page: http://int.lanl.gov/education/

LANL Student Association: http://sa.lanl.gov/

LANL Student Association Calendar: http://sa.lanl.gov/june03.htm

Please feel free to contact Alexis Lavine, EES Division Student Liaison, with any questions regarding mentoring or student internships.

Transitions - A Rock Solid Message from Terry Wallace

Calvin, the youthful philosopher from the comic strip, "Calvin and Hobbes," sums up the inevitably of change with the quote, "Know what's weird? Day-by-day, nothing seems to change, but pretty soon, everything's different." EES Division seems to be in a constant state of transition, although in the last month, the rate of change seems to be accelerating. In addition to a change in leadership in the division office, a large number of our staff have decided to retire by July 1. It would be easy to focus on the uncertainty and anxiety associated with the transitions, but there are a number of remarkable constants about the division that point towards a very bright future. The recent Division Review Committee ranked the division as mostly outstanding, and praised the excellent quality of the science done within the EES groups and programs. This same excellence is recognized and valued within the Laboratory, and I am quite certain that the profile and portfolio of EES's science will grow in the next year. **I have also been impressed with the leadership in the division; the Group Leaders, Deputies, and Program Managers have done an exemplary job and have the skills to successfully navigate the challenges that face the Laboratory**. I am also extremely impressed with the Science and Engineering Leadership Team (SELT). The **SELT continues to provide an extraordinary forum for our scientific excellence** and the remarkable success in LDRD proposals is just one of testaments to the effectiveness of the SELT.

I take comfort in the **rock-solid foundation of the EES Division**. Although the changes swirling around and within the division may be the source of distraction, I have faith that opportunities abound and that the division will continue its positive course.

Reminder - Nanos EES All Hands

The rescheduled Director's Walk around and EES All Hands with Director Nanos is now scheduled for July 10 from 1:45-3:45. The tour will begin at TA-3/43 (the Administra-

tion Building) and includes buildings TA-3/40, 494, 473, and 462. The Director will meet with the Division members for an "All Hands" in P-Auditorium, TA-3/215, beginning at approximately 2:45-3:00. Please plan on attending.

In addition, *Craig Pearson* offered to present any questions that anyone wants asked, anonymously or otherwise, to Pete at the meeting. Please send your questions directly to Craig @ cpearson@lanl.gov. Also, please feel free to ask your questions openly and in person during the EES all hands.

Organizational & Financial Updates will be provided in detail in the July Newsletter

Service Anniversaries & Congratulations to the Following:

Jim Blacic, EES-11, 25 years
Carol Ladelfe, EES-11, 25 years
Rebecca Johnson, EES-IGPP, 20 years
Daniel Taggart, EES-12, 15 years
Giday WoldeGabriel, EES-6, 15 years
Bill Carey, EES-6, 10 years
Frank Perry, EES-9, 10 years
Cliff Meyer, EES-2, 5 years
Bill Stone, EES-6, 5 years
Mike Taylor, EES-7, 5 years

News from the Science and Engineering Leadership Team

Manvendra Dubey, Chair,
5-3128, dubey@lanl.gov

In June, the SELT completed an analysis of the EES-Division Review Committee (DRC) requested survey on the uncertain future of UC management of Los Alamos. We received 119 responses from EES employees, including most of the Division's TSMs. We are finalizing our report that will be submitted to the EES DRC, the EES liaison to the UC, and to EES employees. The key findings include:

1. Nearly 60 percent of respondents came to work at LANL in whole or in part because of the connection to UC.

2. Nearly 60 percent of respondents would consider a major career change (retirement or relocation to another job) if UC were no longer to manage Los Alamos, even if another university system were to take over the contract.

3. The vast majority of respondents preferred UC to maintain its sole management role. Failing this, another university system as manager was strongly preferred, though many respondents indicated that UC was the only viable choice for them.

4. Nearly 10 percent of respondents favored a university/defense contractor partnership to run LANL, though some of these respondents indicated that they felt this way only if UC was the university partner. A few respondents chose a defense contractor as their first or second choice to manage the Laboratory.

5. Prominent employee concerns if the UC contract were lost included:

(a) Loss of experienced employees and corporate memory;

(b) Loss of academic freedom and scientific excellence, with less basic research;

(c) Recruitment of top candidates will suffer, loss of prestige, less credibility in non-weapons areas; and

(d) Lower morale, greater uncertainty, and reduced benefits.

The SELT hosted an EES staff briefing by *Ray Stults*, LANL's DOE Office of Science (OSC) Program Director, on opportunities, initiatives, and trends in this $3.2 billion/year national mission of which **Los Alamos gets ~$80million/year**. We learned that there is a shift within OSC to larger long-term multi-disciplinary team projects to support DOE's mission that should allow academic partnerships to be leveraged more effectively. Ray also stressed that the OSC is making a concerted effort to double its budget in the next 5-6 years, analogous to what the NIH and NSF have recently done. They are focusing on the fact that Office of Science is the primary source of support of Physical Sciences nationally, and this area must be strengthened. Ray also encouraged us to be proactive by touting our LDRD funded activities relevant to Office of Science, to facilitate entry into programs, particularly new initiatives. Ray's presentation will be available on the EES-SELT web site.

The SELT also learned about proposal development from *Diane Stults*, who is at the IGPP and is leading a new effort to improve our success rate, particularly with the Office of Science. She shared her insights and methodology on how to develop winning proposals. Diane is developing a **web-based resource** that will make her methods accessible to all EES staff.

The SELT also provided input to Tom Meyer ADSR on the advertisement for the EES-DL advertisement. Building on the experience with the Center for Homeland Security programs, the SELT is also focusing on other EES program activities to help facilitate communication and integration of our science.

NEW Service

SciSearch Plus, Science Citation index NEW from the Research Library @http://search.lanl.gov

Also, the link can be found on the EES web pages, for your convenience.

Weekly Highlights / Accomplishments sent to ADSR

Natural Analogue Studies at Peña Blanca, Mexico Support Yucca Mountain

Natural analogues provide a line of evidence that supports the understanding of how natural and engineered processes could occur over long time frames and large spatial scales at the proposed Yucca Mountain, Nevada nuclear waste repository. Ardyth Simmons and Ron Oliver, Earth and Environmental Sciences Division, and Mike Murrell and Steve Goldstein, Chemistry Division, at Los Alamos National Laboratory, reported that studies of uranium-series disequilibria within and around uranium deposits can provide valuable information on the timing of actinide mobility and hence the stability of a potential repository over geologic time scales. The Nopal I uranium deposit at Peña Blanca, Mexico, is situated in unsaturated tuff that is similar in composition to the Topopah Spring Tuff of Yucca Mountain and closely matches other evaluation for suitable natural analogues. By modeling the observed radioactive isotope disequilibria at Nopal I, it is possible to estimate the rates of sorption-de-sorption and dissolution-precipitation of the radionuclides over time. Such information is vital to the testing of and confidence building in performance

assessment models for geologic nuclear waste disposal. Since 1999, Los Alamos National Laboratory and Lawrence Berkeley National Laboratory (under the auspices of the Yucca Mountain Project), in cooperation with the Autonomous University of Chihuahua and the University of Southern California, have been engaged in a study of radionuclide transport at Peña Blanca. Results of this study to date are reported in Los Alamos publication, LA-UR-03-3250 or http://www.ees.lanl.gov/Capabilities/geology/index.shtml.

Los Alamos' Carney Named to Mining Review Board

Robert Swift and Theodore Carney of Los Alamos' Earth and Environmental Sciences Division attended the Mining Review Board meeting in Las Vegas, Nevada on May 28. Theodore Carney was introduced as the new Los Alamos board member, replacing Robert Swift on the Mining Review Board. The board reviewed a mining plan proposed by Lawrence Livermore National Laboratory (LLNL) in their section of the U1A complex. The U1A complex is a test facility at the Nevada Test Site used for sub-critical hydrotest experiments that may be used for the evaluation of site-specific monitoring of nuclear tests. Recommendations were made to the board on the LLNL proposal and the new mining proposal was accepted.

Los Alamos Participates in Advanced Concept Technology Demonstration (ACTD) Meeting

Robert Swift and Theodore Carney, Earth and Environmental Sciences Division, and David Steedman, Decision Applications Division, represented Los Alamos at a modeling verification and validation meeting in Albuquerque, New Mexico on May 21. The ACTD is associated with ground shock and facility response, experimentation, and modeling. The customer for this effort is STRATCOM. Planning and issues associated with modeling, sub-scale tests, intermediate scale tests, and full-scale demonstration tests were the focus of the ACTD meeting.

Los Alamos and Massachusetts Institute of Technology Team on Seismic Scattering

Dr. Michael Fehler, Los Alamos' Earth and Environmental Sciences Division, is teaming with Professor Haruo Sato from Tohoku University in Sendai, Japan for five weeks at the Earth Resources Laboratory at Massachusetts Institute of Technology. Fehler and Sato presented a one-day seminar on seismic scattering on May 29.

The seminar team of Fehler and Sato presented findings that show heterogeneities in the earth's crust and lithosphere scatter seismic waves, which propagate over distances of tens to hundreds of kilometers producing a complex seismic envelope called seismic coda. The seminar discussed a general overview of observations of the coda of earthquake seismograms and discussed simple observations and measurements that can be made from them. Fehler and Sato briefly introduced the various modeling approaches that have been used to investigate coda formation and the influences of scattering on seismograms. They presented a mathematical methodology for synthesizing the envelopes of local and regional waveforms in random media that are realistic models for the heterogeneous earth's crust. Finally, they presented a formulation of the radiative transfer theory for the spherical earth that can be used to model long period surface wave observations from large earthquakes. The f-k analysis of coda up to 20 hours from the origin time of earthquakes for periods from 90 to 180 sec. allows the determination of the intrinsic Q of higher modes of spheroidal oscillation.

Additional topics covered in the seminar included: a general introduction to seismic coda; Numerical synthesis of seismogram

envelopes in 2D Random Media; Hybrid Synthesis of Scalar Wave-Envelopes in 2-D Random Media Having Rich Short-Wavelength Spectra; and Constituents of Long-Period Vertical-component seismograms and Modeling of Their Envelopes.

Bayesian Approach to Tomographic Problems Published by Los Alamos Scientists

Research by Los Alamos scientists in the Earth and Environmental Sciences Division was recently published in the Bulletin of the Seismological Society of America. The research describes a Bayesian approach to tomographic problems and the use of data augmentation to handle data censored by poor signal-to-noise; the approach also reduces the bias in the final attenuation models. The publication is available in:
Taylor, S.R., X. Yang, and W. S. Phillips, Bayesian Lg attenuation tomography applied to eastern Asia, Bull. Seism. Soc. Am., 93 795-803, 2003.

Los Alamos' Pearson and Industry Colleagues Publish Results for Discriminating Man-Made Events from Nuclear Explosions

Experimental results of regional propagation of seismic energy from large mining explosions in a Northern Arizona coal mine was recently published in the Bulletin of the Seismological Society of America. These observations are important to help discriminate industrial seismic events from naturally occurring earthquakes and other man-made seismic events such as nuclear explosions or collapse of deep mines. Dr. D. Craig Pearson is the Acting Deputy Division Leader of
Los Alamos' Earth and Environmental Sciences Division and is respected for his seismic-field experiments associated with acquiring ground-based measurements that are associated with mining blasts within the US and overseas. The publication is available in: Bonner, J. L., D. C. Pearson, and
W. S. Blomberg, Azimuthal Variation of Short-Period Rayleigh Waves from Cast Blasts in Northern Arizona, Bull. Seism. Soc. Am., 93 724-736, 2003.

Yucca Mountain Conducts Tours for Bechtel SAIC, British Parliament, Nuclear Fuels, and Taipei

On June 3 and 4, Bruce Reinert, Earth and Environmental Sciences Division's Yucca Mountain Project, conducted tours for the following: Bechtel SAIC Corporation Board of Managers, Joseph Craver, Pail Divjak, and Eman Salama; members of the British Parliament, John Cunningham, MP and
Stephen Lanyman, MP; and representatives of British Nuclear Fuels, Ltd. were also in attendance.

The Taipei Economic and Cultural Office toured on June 4 and included
Dr. Kuan-Hsiu Hsiao, Director of Science Division, Tseng Hsiung, Coordinator of Science Division, and Hsuen-Hsiang Lu.

Los Alamos Geologist Discovers Earliest Human Species

Giday WoldeGabriel, a geologist at
Los Alamos National Laboratory, is the co-leader of a team led by scientific indigenous Africans studying their ancient African ancestors. The latest discovery of Herto crania is the world's earliest Homo sapiens and was unveiled on June 11 in Addis Ababa, Ethiopia. According to Tim White, a researcher and leader of the anthropologists at the University of California Berkeley, the unveiling will "coincide with the publication of companion papers in Nature under a cover illustration featuring the exceptional reconstructions of Jay Matternes. Media interest has been high, and Herto will be featured prominently around the world.

The Ethiopian-born WoldeGabriel dedicated much of his own time during the last decade helping to rewrite the history of human evolution. WoldeGabriel has been a key player in some of anthropology's most significant discoveries; he provided geological and paleoenvironmental contexts for the remains of some of human kind's oldest ancestors. He is the lead geologist and co-principal investigator with University of California, Berkeley, professor Tim White, on the Middle Awash Project.

For more information:
http://www.berkeley.edu/news/media/hominid/
http://teles.berkeley.edu:8080/ramgen/2002/special_events/publicaffairs/fossil.rm

IGPP Los Alamos Orson Anderson Scholar's Book a Must for Seismologists

A review by Thorne Lay in EOS, Volume 84, Number 21, May 27, of the new Paul Richards book, "Quantitative Seismology", Second Edition, is described as "The definitive compendium and reference for elastodynamic theory and is a must-have for all seismologists."

Dr. Richards was an Institute for Geophysics and Planetary Physics (IGPP) Orson Anderson Scholar at Los Alamos from March 1997 - September and spent some of that time working on the book. He is currently the Mellon Professor of the Natural Sciences in the Lamont-Doherty Earth Observatory at Columbia University. His research interests include Seismology; detection of underground nuclear explosions and their implications in both science and politics; and the dynamics of the Earth's inner core. From Richards' scientific work scientists can learn details of the Earth's internal structure and of fault motion in earthquakes, as rock spontaneously fractures and moves to reduce stress.

Los Alamos' Edwards, Hawkins, and Wohletz Attend Nonproliferation and Arms Control Technology Working Group

Geophysicists from the Earth and Environmental Sciences Division, C. L. Edwards, Ward Hawkins, and Kenneth Wohletz, attended the Nonproliferation and Arms Control Technology Working Group (NPAC TWG) meeting at Lawrence Livermore National Laboratory on June 13. The meeting focused on issues of near-field monitoring in nuclear explosion detection.
Hawkins and Wohletz presented a review of the nuclear testing limitations program of the DOE/NNSA Office of Nonproliferation Policy; they presented a description of the staged approach for monitoring technology evaluation, a multi-laboratory effort led by Wohletz and Hawkins that provides technology essentials in support of policy decisions.

Nuclear Energy Institute and Women in Nuclear Tour Yucca Mountain

Tours during the week of June 16-19 for the Yucca Mountain Project (YMP) were conducted by Dick Kovach and Bruce Reinert, Los Alamos' Earth and Environmental Sciences Division's YMP group. Organizations and attendees included: Approximately 200 Nuclear representatives from across the world who were attending a conference in Las Vegas for the Nuclear Energy Institute/ Women in Nuclear. One of the attendees (and speaker at the conference) was Greta J. Dicus, a Commissioner with the Nuclear Regulatory Commission. A group of individuals from NNSA (Nevada Test Site) were toured on June 19 and included Bill Potter, Chief Liaison; Ronald Cstagno, Chief of Applied Engineering; Jim Bieda, Senior Technical Director; Mark Brooks, Head of Computer Applications;
James Milward, Head of Engineering Development; Tony Parr, Chief of Research and Development; Steve Smidt, Chief of Special

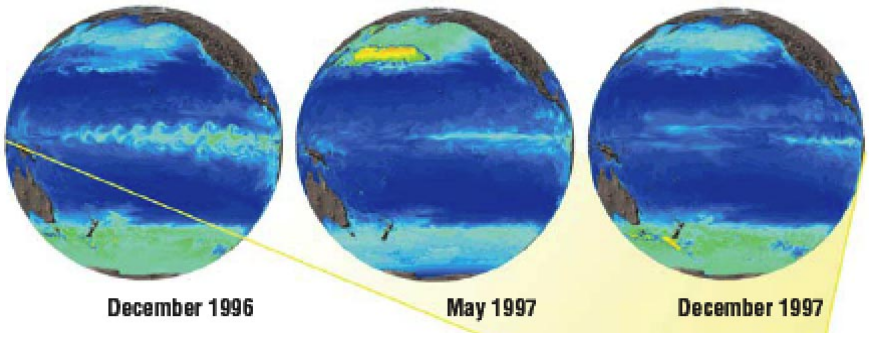
Technology Applications; Tony DiClementi, Chief of Engineering Research; and Brian Donovan, Senior Scientist.

Winner of the May Mystery Image:

1st Place: Shaoping Chu, EES-2

It is El Niño/La Niña

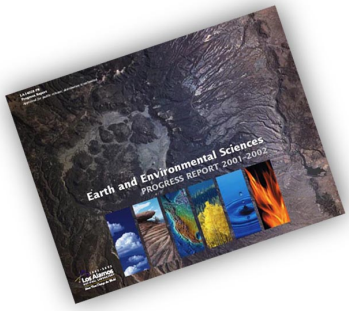
This was easy for Shaoping because she recognized her own work. Shaoping's research area is in ocean biogeochemistry and carbon cycle studies. She provided the following information.



For several years, the Los Alamos ocean modeling team has been introducing biogeochemistry routines into its Ocean General Circulation Model (OGCM). Through developing detailed models for describing ocean biogeochemical cycles/carbon cycling and climate relevant trace gas emissions, we investigate the coupling of the Earth's climate and global biogeochemical systems; we study possible linkages and feedbacks occurring between physics, biology, and chemistry; we help clarify the efficiency, benefits, and environmental ramifications of marine carbon management plans; and we contribute to the development of the Community Climate System Model (CCSM).

The background on this subject, as presented in the 2001-2002 Progress Report, states: "Our biogeochemistry model includes many nutrients, organisms, trace gases, and processes that influence the carbon cycle. The figure displayed demonstrates our model's ability to simulate major features of global marine biogeochemical processing. Snapshots in the figure show the impact of El Niño/ La Niña events on marine ecosystem: surface chlorophyll distribution in late 1996 (a La Niña year), May 1997(onset of a strong El Niño) and late 1997 (full El Niño conditions). Biological activity is intense across the equatorial Pacific during La Niña (Dec 96). The warm pool then shifts eastward, shutting off the supply of nutrient from the deep (mid 97). Plankton growth slows, and the chlorophyll peak gradually recedes towards the east (Dec 97)." For more information, refer to page 31 of the 2001-2001 EES Progress Report.

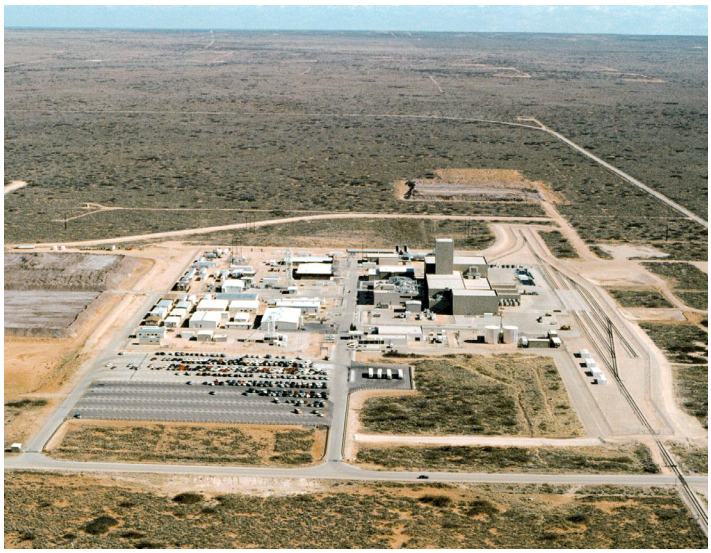
http://www.ees.lanl.gov/pr/index.shtml



Dottie's Mystery Image for June (right): what is the location of this image?

- *Is this an image of*
- *U1A Test Facility at Nevada Test Site?*
- *Waste Isolation Pilot Plant in Carlsbad, NM?*
- *Hanford Site in Washington*

Respond to: dot@lanl.gov



EEScience

Guest Editorial

The Surprisingly Small-Felt Earthquakes of Los Alamos

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Peter Roberts, EES-11
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Background

Earthquakes do not often intrude into our lives here in New Mexico. As a result, many people are not aware that earthquakes are, nevertheless, a part of our physical environment. Los Alamos is situated along the western side of the Rio Grande Rift, a major tectonic feature of North America. The rift is the site of a very slow opening or spreading of the North American continent. Each month, several small earthquakes (called micro earthquakes) occur in north-central New Mexico. Group EES-11 (Geophysics) operates a network of instruments to record and locate these earthquakes, and in a typical month, the network detects one or two that are large enough to be located. The vast majority of these escape notice by most of us. Infrequently, though, an earthquake occurs that is felt. Since the Laboratory's founding 60 years ago, a total of nine earthquakes have been felt in Los Alamos. Five of these occurred after installation of earthquake monitoring instruments about 30 years ago. Thus, we have both felt reports and instrumental information about them. All five of these felt and recorded earthquakes were quite small - their magnitudes were about 1.5 to 2. It is unusual for earthquakes as small as these to be felt. Most felt earthquakes are much larger, typically magnitude 4 or larger.

Recent Felt Earthquakes

Earthquake monitoring instruments have been operated in the area around Los Alamos for about 30 years. All five earthquakes that were felt during that time occurred in just the past 12 years. Figure 1 shows the epicenters of earthquakes in the Los Alamos area from 1973 through 2002, along with the epicenters of the five felt earthquakes indicated in red. The epicenters of all five felt earthquakes lie to the north or north-west of Los Alamos.

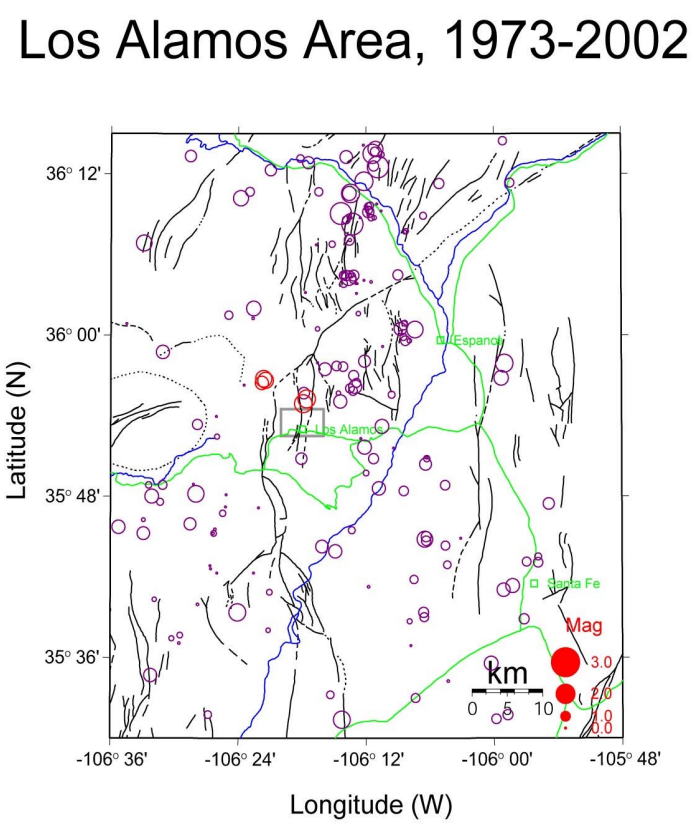


Figure 1. Map of earthquake epicenters in north-central New Mexico located by the Los Alamos Seismograph Network (LASN) from start of operation in 1973 through 2002, along with epicenters of the April 2003 felt earthquakes. Epicenters of the five earthquakes that have been felt in Los Alamos since 1973 are plotted in red circles, the remaining epicenters are plotted in purple circles; the size of the earthquake symbols are scaled to magnitude. Faults are shown in black, rivers in blue, and major highways in green. The small gray rectangle that includes Los Alamos is the area shown in **Figure 2** (below). The largest earthquakes plotted are about magnitude 3; most earthquakes are magnitude 2 or smaller. The figure encompasses an area about 80 km (N-S) by 70 km (E-W).

Figure 1

The five felt earthquakes occurred in 1991 (two; both on February 3, local time), in 1998 (on November 27), and in 2003 (on April 5 and 21, local time). The magnitudes of these were all less than 2.0. The two earthquakes felt in 2003 are the most recent, and we focus on the one from April 21, which was the larger and more widely felt of the two. This earthquake had a magnitude of about 1.7. The magnitude of an earthquake is determined from instrumental measurements of ground motion, represents a single measure of the size of an earthquake.

In contrast to magnitude, the felt effects of an earthquake are different from one site to another. A significant factor in whether a small earthquake is felt is what time of day it occurs. Small earthquakes that occur during the daytime when people are generally physically active are not as likely to be felt. The five felt earthquakes occurred during the evening or early morning hours, when many people were at home and less physically active than they would be during other times of the day.

The area over which the five earthquakes were felt is generally similar, as is the range of Intensities assigned to the felt reports for all five earthquakes. The geographic distribution of felt reports for all five earthquakes is limited by the distribution of homes in Los Alamos.

April 2003 Earthquake

Figure 2 (below) shows the distribution of the intensities assigned to the felt reports from the most recent felt earthquake, on April 21, 2003 (local time). Intensities depicted in Figure 2 are based on what is called the Modified Mercalli Intensity scale (Bolt, 1991). Earthquake Intensities are assigned based on the effects of the earthquake on people and structures. Intensity varies from place to place for a given

earthquake, and it depends on the size (magnitude) of the earthquake, the distance of the site from the epicenter, and local site effects. Local site effects result predominantly from the geological conditions at the site, although the type of structure and how tall it is has a large effect, as well. A site at which the geological material at the surface is rock generally will experience less shaking than one at which it is soil. The height of the structure at the site will also influence the amount of shaking that an earthquake observer experiences. Although buildings in Los Alamos are typically only one to three stories high, an observer on the second or third floor of a building generally will be subjected to larger motions from an earthquake than one on the ground floor.

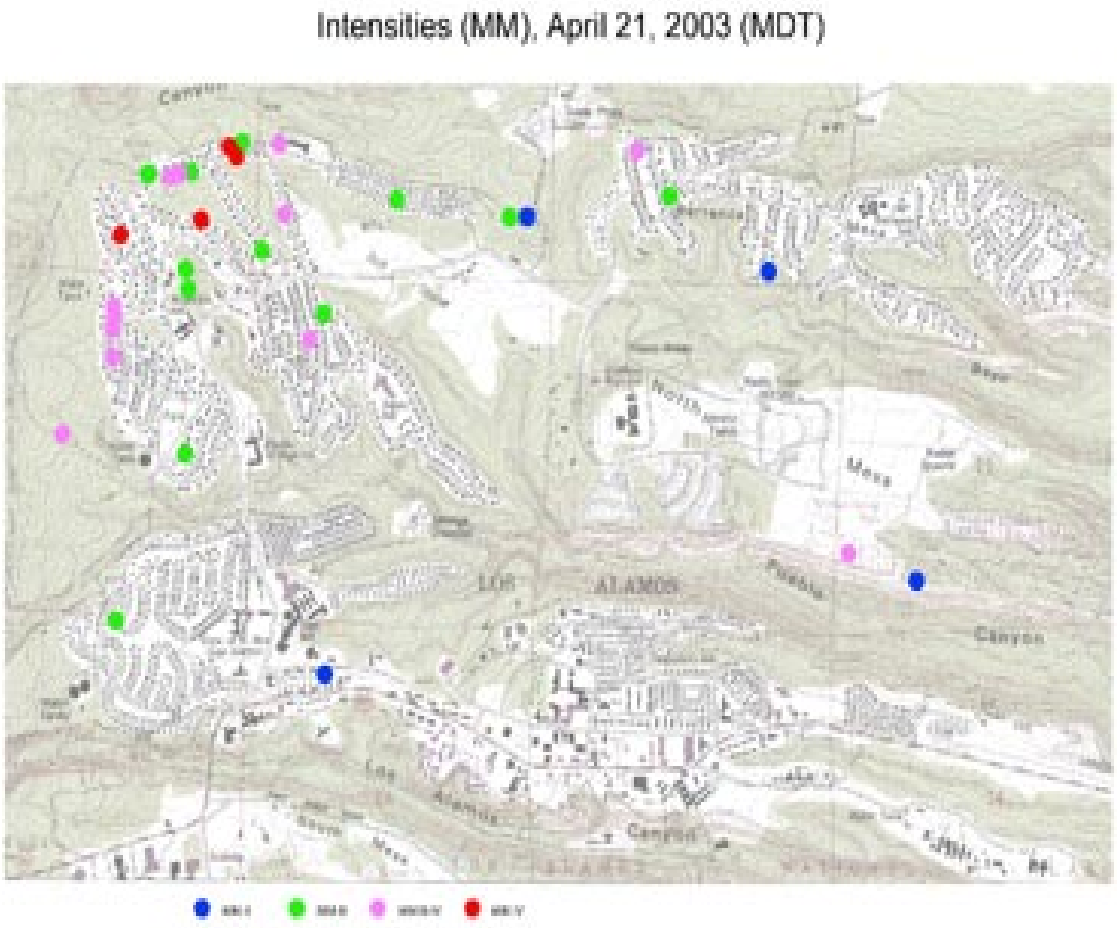
Figure 2 (below). Plot of Intensities for the April 21, 2003 (MDT) felt earthquake. Intensities were assigned from felt effects using the Modified Mercalli Intensity scale (Bolt, 1988). The intensities are superposed on a portion of the 1:24,000 scale "Guaje Mountain" topographic map from the U.S. Geological Survey. The area of the figure is about 4 km (N-S) by 6 km (E-W).

The Modified Mercalli Intensities plotted in Figure 2 range from Intensity II to IV. As described by Bolt (1991), Intensity I is assigned if the earthquake was only felt by a few people who may have been in very "favorable circumstances". Intensity II is assigned if the effects were felt only if a person was "at rest", not walking around. Intensity III is assigned if the effects are "felt quite noticeably indoors", though the effects may not be recognized as having resulted from an earthquake. Intensity IV is assigned if the effects were felt by many people who are indoors though perhaps not by people outdoors. Higher intensity effects reported in this earthquake included the rattling of windows and delicately balanced objects. Suspended plants or light fixtures swayed and many sensed a rolling, wavelike motion pass through their home.

The area over which the April 21, 2003 earthquake was felt is about 15 sq. km. That is a small area, and represents only a small fraction of the area over which the earthquake probably could have been felt had there been people living all around the epicenter.

Are there any larger earthquakes?
Los Alamos is situated along the western side of the Rio Grande rift, which is a zone in which Earth's crust is slowly extending in a roughly east-west direction at a rate of less than a MM. per year. The rate of opening of the rift was estimated from the distance between features that once were believed to be adjacent, and represents an average over an interval of tens of millions of years. The extension across the Rio Grande rift produces earthquakes as the crust shifts to adjust to the extension. In historic time, the largest earthquake that has occurred in north-central New Mexico was the Cerrillos earthquake, which occurred in 1918 (Olsen, 1979). There are no instrumental recordings of this earthquake, and Olsen (1979) estimated its size as magnitude 4.5 to 5.5 from the felt area and maximum Intensity. Other significant earthquakes in New Mexico include a swarm of earthquakes that occurred in Soccoro in 1906. Several of these earthquakes did damage, cracking adobe walls and toppling chimneys, with estimated magnitudes of 6 or higher.

Instrumental data about earthquakes in north-central New Mexico have been recorded by varying types and distributions of stations for nearly 100 years. Although long compared to the lifetimes of individuals, that time interval is short by comparison to the time scale of geologic processes. To better understand the earthquakes that have occurred over longer time intervals, we study prehistoric earthquakes with paleoseismic studies. These involve the excavation of trenches in the near-surface (generally soils) across fault zones. The purpose of these trenches is to identify



Key to Dots:
Blue = II
Green = III
Pink = III-IV
Red = IV

episodes of surface rupture that have occurred, and to date when they occurred. A number of trenches have been excavated and mapped in the Los Alamos area (Gardner et al., 2001). These have sampled the three faults that are shown on Figure 1 in the Los Alamos area. Surface rupture episodes have been identified that correspond to earthquakes as large as magnitude 6.5 to 7. The time between repeated earthquakes of that magnitude (termed recurrence interval) is not yet well known, though it is probably several thousand years with the most recent of these large, prehistoric earthquakes at about 2000 years ago.

Summary

Though Los Alamos and north-central New Mexico are not often subjected to earthquakes that can be felt, several have occurred that were felt in Los Alamos. These were all very small (magnitudes less than 2), and they were able to be felt because their epicenters were close to residential areas. Five felt earthquakes were recorded and located by the Los Alamos Seismograph Network. These locations confirmed that the epicenters of the felt earthquakes were quite close. Historic felt reports extend the record of earthquake activity back for about 100 years, during which time earthquakes as large as about magnitude 6 have occurred in New Mexico (Sanford, et al,

1991). By using paleoseismic trenching, a record of earthquakes can be extended back many thousands of years. During that time, earthquakes as large as magnitude 6.5 to 7 appear to have occurred in the Los Alamos area. Earthquakes in the Los Alamos area probably result from geologic processes related to the slow opening of the Rio Grande rift.

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